PB-228 805

WATER RESOURCES STUDY BAYOU TECHE AND VERMILION RIVER LOUISIANA

Public Health Service
Dallas, Texas

July 1963

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WATER RESOURCES STUDY

BAYOU TECHE AND VERMILION RIVER

LOUISIANA

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Division of Water Supply and Pollution Control
Dallas, Texas

In Cooperation with the

DEPARTMENT OF THE ARMY
U.S. Army Engineer District--New Orleans, Louisiana

July 1963

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I. INTRODUCTION

Authority

In a letter dated June 29, 1962, the U.S. Army Engineer District, New Orleans, Louisiana, requested the Department of Health, Education, and Welfare's " . . . views on the pollution problem in Bayou Teche and the need for municipal and industrial waters from Bayou Teche and Vermilion River and value thereof . . . ." This study complies with provisions of (1) the Federal Water Pollution Control Act (Public Law 84-660) as amended by Public Law 87-88, and (2) the Water Supply Act of 1958 (Public Law 85-500, Title III) and a Memorandum of Agreement between Department of the Army and the Department of Health, Education, and Welfare dated November 4, 1958.

Purpose and Scope

This report indicates the water requirements for municipal and industrial and water quality control purposes to the year 2020 in the Bayou Teche and Vermilion River basins. Estimates are made of the benefits attributable to the Federally constructed works which will provide water for these purposes.

Acknowledgments

The cooperation of many persons and agencies is gratefully acknowledged. Special appreciation is expressed to the following:

U.S. Army Engineer District, New Orleans. Louisiana
Louisiana Stream Control Commission, Baton Rouge, Louisiana
Louisiana State Board of Health, New Orleans, Louisiana
Louisiana Department of Public Works, Baton Rouge, Louisiana
Geological Survey, Ground Water, Surface Water and Quality of Water Branches, Baton Rouge, Louisiana
Water departments, officials and Chambers of Commerce of the following cities: Port Barre, Lafayette, New Iberia, Morgan City
Central Louisiana Electric Company, New Iberia, Louisiana

II. SUMMARY AND CONCLUSIONS

Summary

1. The study area comprises six parishes in southern Louisiana, all or part of each being located within the watersheds of Bayou Teche and Vermilion River. The area's terrain is extremely flat, marshy, and interlaced with many poorly defined streams.

2. Agriculture is the mainstay of the study area's economy and accounts for a major portion of its water requirements. Large withdrawals of water for agriculture affect water quality in the Teche-Vermilion basin by reducing the amount of water available for the dilution of wastes.

3. The water quality of the existing and firmly planned sources is acceptable for municipal, industrial, and agricultural uses.

4. The project design incorporates the following base streamflows in the system: (a) seven day low flows with an exceedence of 90 percent during the irrigation season and (b) monthly low flows with an exceedence of 98 percent during the remainder of the calendar year.

Conclusions

1. To insure continued growth, careful planning for efficient development of all of the study area's water resources is essential. Realization of the full potential of these resources for municipal, industrial, agricultural, navigational and recreational purposes will be possible only if present and future pollution in the area is controlled. Since secondary waste treatment alone cannot at present accomplish this control, provision of flow regulation to maintain minimum quality conditions in the Teche and Vermilion watersheds must be made a part of the water supply plan.

2. The study area's population is expected to grow to 670,000 by the year 2020 from a base of 334,557 in 1960.

3. Projected municipal and industrial water supply needs are 374 mgd (million gallons per day) in 2020 for the six-parish study area.

4. With the water supply plan presented herein, the potential water resources of the study area including imports from the Atchafalaya River basin are sufficient to satisfy all projected area water requirements until the year 2020.

5. To maintain water quality within the Teche-Vermilion basin will require supplemental surface water pumpage of 69,350 million gallons from the project in the year 2020 based on 90 percent removal of biochemical oxygen demand (BOD).

6. The estimated annual project benefits by purpose and project feature are delineated in section VIII of this report. These benefits, which are based on a combination of alternative cost and loss function evaluation, are summarized as follows: municipal and industrial water supply, $248,500; and water quality control $382,400.

III. DESCRIPTION OF PROJECT AND BASIN

Location and Features

The project is located in the Bayou Teche and Vermilion River basins in southern Louisiana as shown in Figure III-1. It consists of the following works to be constructed for the purpose of providing water for municipal and industrial use and quality control purposes on Bayou Teche and Vermilion River in Louisiana.

1. A pumping station and appurtenances at the Courtableau Drainage Structure to lift water from the Atchafalaya Basin into Bayou Courtableau, which would then flow into upper Bayou Teche and into the Vermilion River through Bayou Fusilier and Ruth Canal.

2. A control structure in the Loreauville Canal to prevent the loss of water from Bayou Teche.

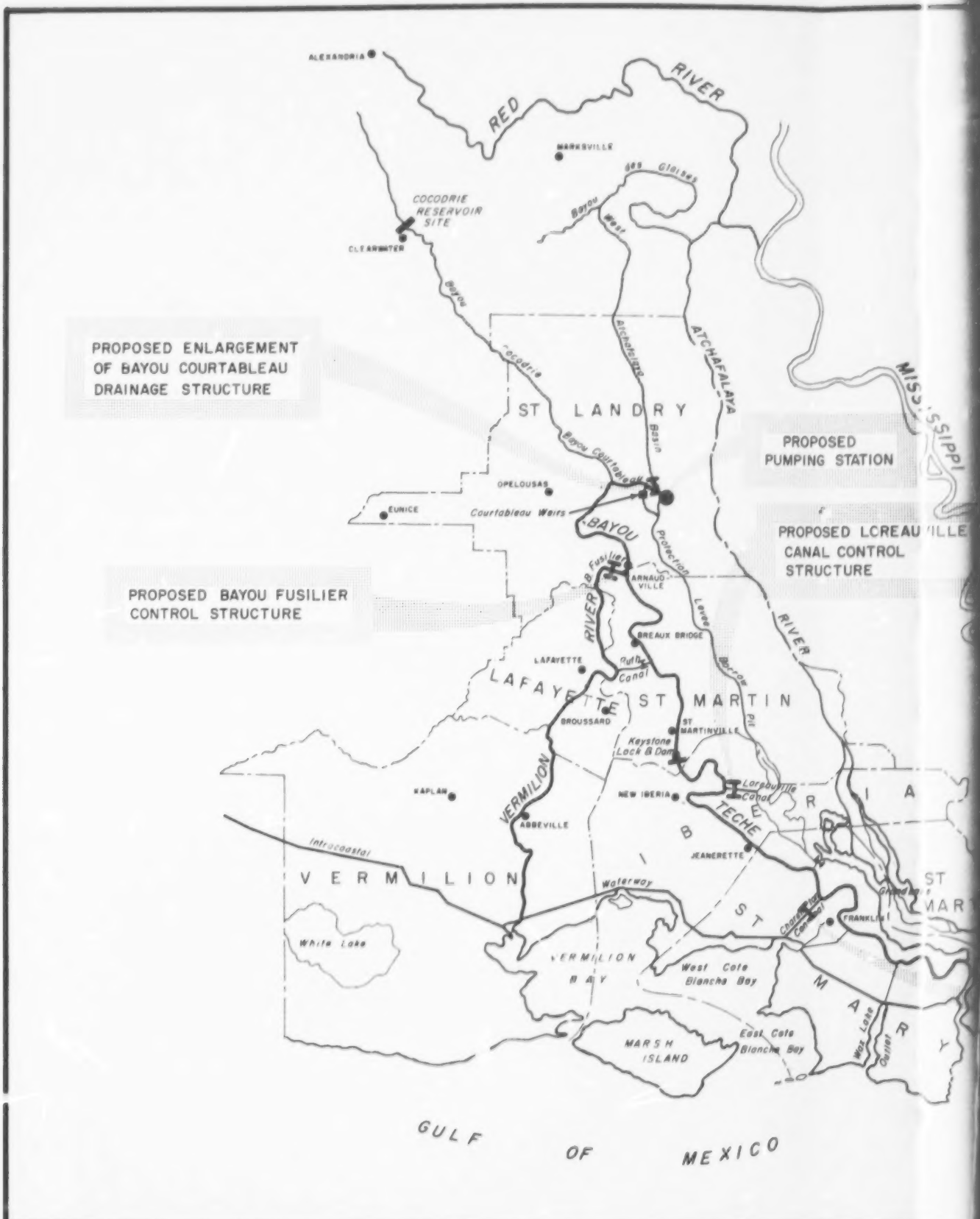
3. A control structure in Bayou Fusilier to control flows from Bayou Teche into the Vermilion River at all stages.

4. A control structure in the Charenton Canal to prevent saltwater intrusion.

5. Enlargement of the existing Courtableau Drainage Structure in the West Atchafalaya Basin Protection Levee for passage of the flood flows.

The Bayou Teche and Vermilion River watersheds cover an area of approximately 2,500 square miles and extend in a southeasterly direction nearly 150 miles from the Red River to the Gulf of Mexico. Bayou Teche and Vermilion River are distributaries of the complicated Bayou Rapides-Bayou Cocodrie-Bayou Courtableau-West Atchafalaya Basin Protection Levee Borrow Pit System. Prior to the construction of the West Atchafalaya Basin Protection Levee (WABPL), about 75 percent of the area was tributary to the Atchafalaya River. When stages are favorable, water is diverted from the watershed at the following points:

1. The Red River at Alexandria.
2. The Red River backwater near Marksville.
3. Atchafalaya River through the Bayou Des Glaises.
4. Atchafalaya Basin Floodway through the Darbonne, Courtableau, and the Charenton Control Structures.


PROPOSED ENLARGEMENT OF BAYOU COURTABLEAU DRAINAGE STRUCTURE
PROPOSED BAYOU FUSILIER CONTROL STRUCTURE
PROPOSED PUMPING STATION
PROPOSED LCREAU ILLE CANAL CONTROL STRUCTURE
ALEXANDRIA
RED RIVER
MARKSVILLE
COCODRIE RESERVOIR SITE
CLEARWATER
Bayou des Glaises
Bayou Cocodrie
Atchafalaya Basin
ATCHAFALAYA
MISSISSIPPI
ST LANDRY
Bayou Courtableau
OPELOUSAS
EUNICE
Courtableau Weirs
BAYOU
Protection Levee
ARNAUDVILLE
BREAUX BRIDGE
LAFAYETTE
Outlet Canal
LAFAYETTE
ST MARTIN
BROUSSARD
ST MARTINVILLE
Keystone Lock & Dam
Lorgbuttle Canal
KAPLAN
NEW IBERIA
VERMILION
ABBEVILLE
TECHE
JEANERETTE
Intracoastal Waterway
VERMILION
ST MARY
FRANKLIN
White Lake
VERMILION BAY
West Cote Blanche Bay
East Cote Blanche Bay
MARSH ISLAND
GULF OF MEXICO

VICINITY MAP

MISSISSIPPI RIVER

PROPOSED LOREAUVILLE CANAL CONTROL STRUCTURE

PROPOSED CHARENTON CANAL CONTROL STRUCTURE

ST MARTIN

Grand Lake

FRANKLIN

MORGAN CITY

West Lake

Outlet

10 0 10 20 30

SCALE IN MILES

WATER RESOURCES STUDY

BAYOU TECHE & VERMILION RIVER, LOUISIANA

LOCATION MAP

U. S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE

PUBLIC HEALTH SERVICE

REGION VII DALLAS, TEXAS

FIGURE III-1

Stream Characteristics

Bayou Teche is a relatively small stream which flows along the highest part of a large alluvial ridge. Contrary to normal conditions, all local drainage is away from the stream and it functions as a flume, conveying waters from Bayou Courtableau to the Vermilion and lower Teche systems. The ridge slopes gently away from the stream into the swamps which lie 5 to 10 feet below the bayou and from 1 to 3 miles away on either side. Bayou Teche is navigable from its mouth to mile 105.2 at Arnaudville. Below the Keystone Lock and Dam, the stream is tidal at low stages.

The Vermilion River on the other hand has a well defined basin, containing 650 square miles, and acts as a distributary of Bayou Teche. It is connected with Bayou Teche by Bayou Fusilier at Arnaudville. Approximately 25 percent of the flow in Bayou Teche is normally diverted to the Vermilion River. 1 29/ Intense local storms however cause an occasional flow reversal in Bayou Fusilier toward Bayou Teche. The Vermilion River is navigable from mile 0 to Lafayette at mile 48.7. The stream is tidal downstream of Abbeville at river mile 23.8.

Streamflow

The flow in the Teche-Vermilion system consists of runoff from the tributary area above Bayou Courtableau and along the Vermilion River, and reverse flow from the Atchafalaya basin through the Courtableau Drainage Structure. All of the runoff east of Bayou Teche flows to the West Atchafalaya Basin Protection Levee Borrow Pit and is not available to the system until it reaches Bayou Teche at Charenton.

When the stage in Bayou Courtableau falls below 18 feet, diversion of water from Bayou Courtableau to the WABPL Borrow Pit through the Courtableau weirs stops.

Total flow in the system at Arnaudville varies from a maximum weekly average of approximately 2,200 cfs 1/ in the period January to June to about 100 cfs 1/ for the remainder of the calendar year.* The flow divides at this point, part going to the

---

*Discharge data in the area are very sparse. Geological Survey records show only six active discharge stations located in the watershed. Of these, three were established in 1959, one in 1953, one in 1946, and one in 1943. The methods used to improve the reliability of these records are explained in Appendix A.

Vermilion River via Bayou Fusilier, with additional water diverted to Vermilion River at the Ruth Control Structure. At the Loreauville Canal, approximately one-half of the remaining flow is diverted to the WABPL Borrow Pit. 1/ This flow is returned to Bayou Teche at Charenton. The distribution of flow in the Teche-Vermilion system is shown in Table III-I.

Table III-1

Distribution of Flow, Teche-Vermilion System 1/
1959-1960

Date	Teche at Arnaud-ville (cfs)	Diverted at Fusilier (cfs)	(%)	Ruth (cfs)	(%)	Teche at Key-stone (cfs)	(%)	Diverted at Loreau-ville (cfs)	Teche at New Iberia* (cfs)
8-17-59	345	70	20.3	181	52.5	94	27.2	47	47
10-20-59	594	171	28.8	223	37.5	200	33.7	100	100
1-18-60	1,230	394	32.0	284	23.1	552	44.8	276	276
2-11-60	964	316	32.8	358	37.1	290	30.1	145	145
4- 7-60	829	269	32.4	321	38.7	239	28.9	120	119
6-15-60	733	230	31.4	447	61.0	56	7.6	28	28
7-14-60	558	131	23.5	288	51.6	139	24.9	70	69
8-11-60	401	80	20.0	207	51.6	114	28.4	57	57
9- 1-60	685	195	28.5	271	39.5	219	32.0	110	109
11-10-60						493		246	247
12-14-60						617		308	309

*Taken from discharge relationship curve.

Ground Water

The massive deposits of Pleistocene sand and gravel in the study area are comparable in productivity to the best water-bearing formations in other parts of the United States. Total study area ground water use in 1960 was approximately 115 mgd. There is no evidence that the ground water resources in the area are being depleted in quantity or that declines of water level in themselves threaten to restrict continued development of this resource on an areal basis. Local problems that are caused by improper spacing of wells can be solved by well relocation or by tapping different strata. The primary threat to the ground water resources of the study area is reduction of water quality by salt water encroachment.

Saline waters from Vermilion Bay are drawn many miles up the Vermilion River during drought years, resulting in potentially serious encroachment into the ground water reservoirs, which are hydraulically connected to the streambed. 29 30 47/

Water Quality

A summary of the present water quality in the study area is shown in Table III-2. 2/

Table III-2 2/

Summary of Present Water Quality Conditions

VERMILION RIVER AT BANCKER'S FERRY, NEAR ABBEVILLE, LOUISIANA (14.5 miles from mouth, and about 6 miles south of Abbeville, Louisiana. Top and bottom samples taken at this station were composited. Period of record--January 18, 1949, to May 10, 1951--62 samples.)

	Concentrations in mg/l		
	Total Solids	Chlorides	Sulfates
Arith. Mean	162	66	6.8
Maximum	1,160	620	82.0
Minimum	32	10	2.0

BAYOU TECHE AT ARNAUDVILLE, LOUISIANA

Date	Discharge (cfs)	Concentrations in mg/l		
		Total Solids	Chlorides	Sulfates
9-20-55	430	94	9.5	4.9

TYPICAL GROUND WATER QUALITY

Item	Well No. I-53 Jeanerette, Louisiana	Well No. I-13 Loreauville, Louisiana	Well No. Lf-491 Lafayette, Louisiana	Well No. Ve-7 Abbeville, Louisiana
Sulfates in mg/l	0.6	1.2	9.3	2.6
Chlorides in mg/l	5.0	5.3	8.2	206.0
Total Dissolved Solids in mg/l	535.0	340.0	195.0	654.0
Date of Collection	10-19-49	9-28-50	10-25-49	10-25-49

The above table indicates chemical water quality ranging from very good to poor. In general, the waters (surface and ground) in upper reaches of the basins can be classified as chemically good. In the lower reaches, maintenance of fresh water flows sufficient to prevent salt water encroachment to the mouth of the streams would preserve the chemical quality of both surface and ground water. The salinity of water entering the Vermilion River from Vermilion Bay seldom exceeds 2,500 mg/l as chlorides (Cl^-). 41/ The density differential between this water and the fresh water is not great enough to require a fresh water supply very much in excess of the diversion demand rate in order to prevent salt water intrusion into the stream channel.

Conversely, the organic quality of the surface waters in the area is relatively poor, especially during the sugarcane grinding season (October through December). Prior to 1954, the waters of Bayou Teche became septic and offensive odors persisted during this season. The principal organic loads imposed on the stream are wastes from a number of raw sugar mills. 45/ The organic load, which has been reduced by treatment from about 53,500 pounds per day of BOD in 1954 3/ to about 15,600 pounds per day of BOD in 1960, 3/ still causes unsightly and unsanitary conditions to occur in Bayou Teche at times during the grinding season.

The present organic load received by the Vermilion River is about 9,200 pounds per day of BOD, more or less evenly distributed throughout the year. 4/

IV. DESCRIPTION OF THE STUDY AREA

Location and Boundaries

The boundaries of the study area are shown in Figure III-1. The area is generally coincident with the boundaries of the Bayou Teche and Vermilion River basins. There are six parishes included in the study area. These, together with the major municipalities in each parish, are shown below in Table IV-1.

Table IV-1

Study Area Parishes and Major Municipalities

Parish	Major Municipalities
Iberia	New Iberia, Jeanerette
Lafayette	Lafayette, Broussard
St. Landry	Opelousas, Eunice
St. Martin	St. Martinville, Breaux Bridge
St. Mary	Morgan City, Franklin
Vermilion	Abbeville, Kaplan

This area was chosen for study because it is the politically bounded entity whose economy and welfare are directly affected by the environment existing in the waters of the Bayou Teche and Vermilion River basins.

Geography

The terrain of the study area is extremely flat, marshy, and interlaced with many poorly defined streams. The soils of the study area are very fertile and suitable for the growth of rice, sugarcane, sweet potatoes, cotton, and many other crops.

The climate is temperate with hot summers and mild winters. The mean annual temperature is about 69°F and the mean annual precipitation of the area is approximately 61 inches. The average length of the growing season is on the order of 260 days.

V. THE ECONOMY

Present

Extractive Industries

Mining 9-12/

The principal minerals in the study area are petroleum, natural gas, natural gas liquids, salt, clays, sand and gravel. This area, which contains only 8.6 percent of the State's land area, is among the most prolific in the production of petroleum, natural gas, and salt. In 1959, crude petroleum production amounted to 54,281,610 barrels, and natural gas production was 537,651,000 million cubic feet. These quantities represent 17.1 percent and 23.3 percent of the crude petroleum and natural gas produced in the State during 1959. According to the Louisiana State Department of Conservation, the extraction of oil and gas in the study area will continue to increase and other natural mineral resources will continue to be developed at a favorable rate. The value of mineral production increased 59 percent or $112.5 million (constant dollar base) from 1952 to 1959.

Agriculture 5/

The principal crops in the study area are rice, sugarcane, cotton, and sweet potatoes. Livestock, especially cattle, sheep, and hogs, is also very important to the agricultural sector of the area's economy. The number of farms and cropland harvested have been decreasing, while the acres of pastureland, total farm land, value of crops sold, and the value of livestock and livestock products sold have been increasing during the period from 1944 to 1959. Agricultural employment has decreased from 37.2 thousand workers or 44.5 percent of the labor force in 1940 to 15.0 thousand workers or 15.1 percent of the labor force in 1960.

Forestry and Fisheries 13-19 27 28/

The study area is in the south delta forest survey region of Louisiana, which is the least forested area in the State--only 29 percent. Due to the large area in marsh and cypress-tupelo gum swamps and the fact that the area in cropland is relatively stable, it is not anticipated that there will be any large scale conversion of cropland to forests in the near future. The area offers a considerable source of pulpwood since over half of the region's hardwood volume is in cottonwood, willow, gums, and other soft textured species.

Fishing is important to the study area's economy, especially in Iberia, St. Mary, and Vermilion Parishes. The 1960 commercial catch was 80,289,900 pounds valued at $5,079,433. These quantities amounted to 14.2 percent of the catch and 19.6 percent of the value of commercial fishing in the State of Louisiana.

Manufacturing 6-8 24 25/

Manufacturing employment in the study area has increased 59 percent or 3,100 workers in the two decades from 1940 to 1960, while the same period increase for the State was 64 percent. Considerable diversification in the manufacturing base has also been evident in the area. Most of the diversification has occurred in the resource-oriented industries (food and kindred products, petroleum, and petrochemicals) with a lesser amount in the marked-oriented industries (fabricated metals and machinery).

The constant dollar value added by manufacturing has increased 97 percent or $25 million from 1947 to 1958. This amounts to an increase of $3,200 per employee in the study area compared to a same period increase of $4,100 throughout the State.

Generally, an increase in employment coupled with increase value added per employee reflects favorably on the prospects of growth in the manufacturing industries.

Population 26/

The population of the study area was 334,557 in 1960. This is an increase of 56 percent since 1910, compared to an increase of 97 percent for the State of Louisiana during the same period. During the decade from 1950 to 1960, however, the rate of population growth in the study area surpassed that of the State.

Future 34/

In general, the economic projections for the study area reflect the long-term levels that might reasonably be reached with production and requirements in balance under competitive conditions.

Mining is expected to continue to be a major contributor to the economy of the study area. Improved technology and productivity, however, will probably result in a decrease in the number of employees in this industry. In 1960, 8,500 workers (8.6 percent of the labor force) were engaged in mining. This figure is expected to decrease to 4,100 workers or 1.6 percent of the labor force by the year 2020.

Agricultural production will most likely continue upward in step with the demand for farm products as created by a growing population. Employment in agriculture is expected to increase from 15,043 workers in 1960 to 16,800 workers in 2020. This represents about 6.6 percent of the labor force in 2020, compared to a 1960 value of 15.1 percent.

The segment of the economy dedicated to forestry and fishing is expected to decrease considerably by the year 2020. The number of workers employed in these industries will probably remain relatively constant (629 employees in 1960). This number will represent only two-tenths of 1 percent of the labor force in the year 2020.

The rapid growth in the manufacturing industries of the study area experienced during the last two decades can be expected to continue. By 2020 manufacturing employment should reach 60,100 workers, representing 23.6 percent of the labor force. This compares to 8,471 workers or 8.5 percent of the labor force in 1960.

The service industries which include sales, insurance, finance, personal services, and transportation employed 61 percent of the labor force or 60,537 workers in 1960. Based on past trends modified by relative growth and income in the area, comparable employment in 2020 will be about 163,000 or 64 percent of the labor force.

A summary of the present and future employment is shown in Table V-1.

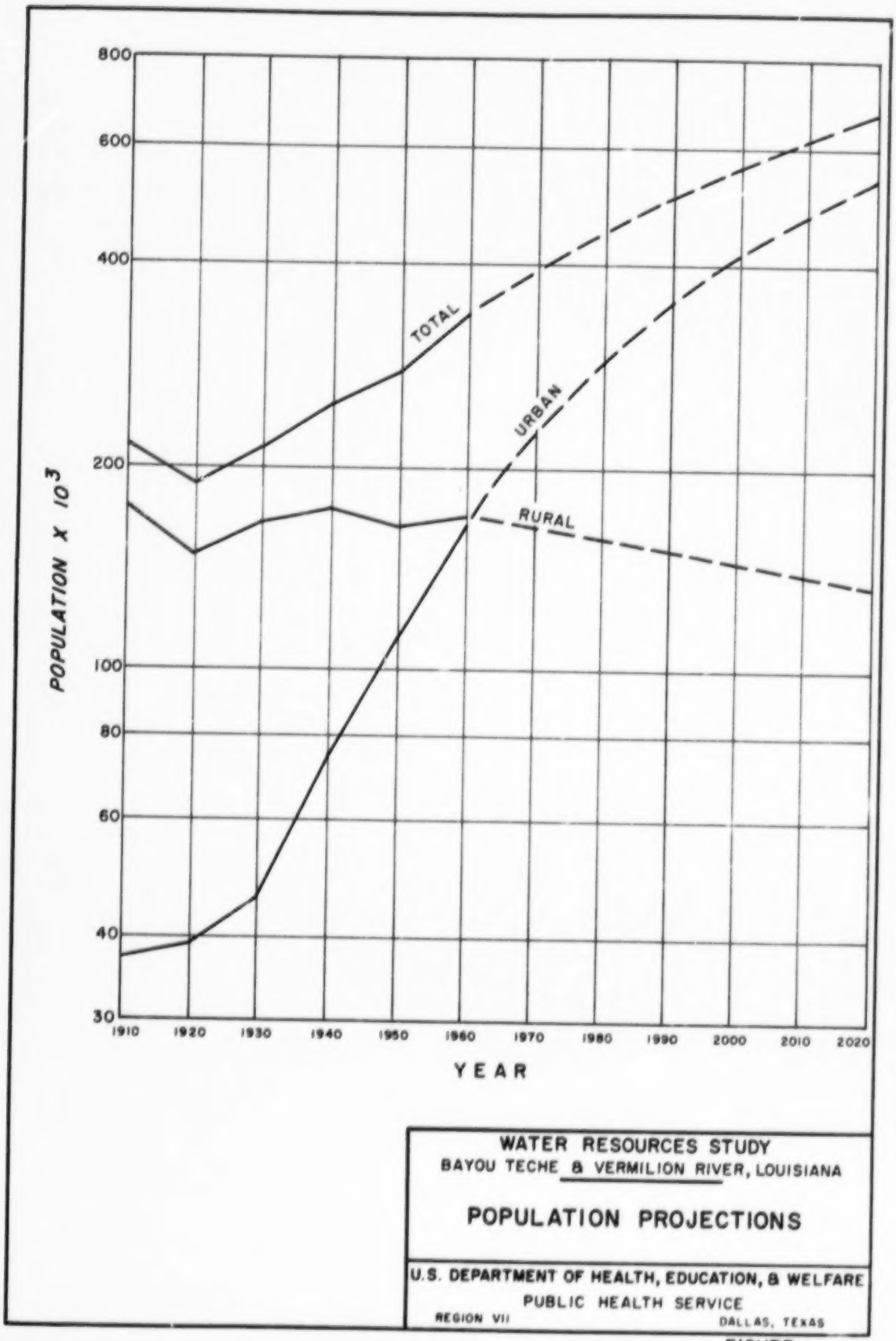
Table V-1 5-22 24-28/

Study Area Employment
Present and Projected

Industry	1960 Labor Force		2020 Labor Force	
	Number	Percent	Number	Percent
Agriculture	15,043	15.1	16,800	6.6
Forestry and Fisheries	629	0.6	600	0.2
Mining	8,538	8.6	4,100	1.6
Manufacturing	8,471	8.5	60,100	23.6
Service Industries	60,537	60.7	163,000	64.0
Unemployed	6,499	6.5	10,100	4.0
Labor Force	99,717	100.0	254,700	100.0

Population Projections

The coastal parishes of south Louisiana which include the six parishes of the study area accounted for 75 percent of the State's population increase between 1950 and 1960. 26/ Indications are that this growth pattern will continue and the population of the study area can be expected to increase at a rate considerably in excess of the State average. Many factors are considered in formulating the population projections. These include: (1) resources and employment analysis; (2) the trend toward urbanization; (3) growth comparisons with cities that were of similar size to the cities of the study area in the recent past; (4) the ratio of growth between study area cities and the State's urban population. The population of the study area is expected to reach 670,000 by the year 2020. The population projections are graphically illustrated in Figure V-1.



WATER RESOURCES STUDY
BAYOU TECHE & VERMILION RIVER, LOUISIANA

POPULATION PROJECTIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE V - 1

VI. WATER REQUIREMENTS

General

The term water requirements encompasses a multiplicity of uses which are dependent upon a large number of variables. Although primarily concerned with municipal and industrial water use, this study examines other water uses that affect the supply and demand for water within the study area. The probable future water requirements of the study area in the year 2020 are based on economic projections, coupled with analyses of unit water requirements.

Municipal Water Use

Municipal water is defined here as being municipally supplied water for all purposes excluding that supplied to industrial establishments. Included in the resulting per capita quantities are losses in the distribution systems and treatment plants.

Future municipal water needs are calculated by multiplying the estimated 2020 per capita use by the projected population in the area which will be served by municipal water systems. The unit municipal water use for the year 2020 is expected to be 160 gallons per capita day. On this basis, the municipal water requirement for the study area is estimated to be 86 mgd in the year 2020.

Industrial Water Use

The definition of industrial water used here refers to all water regardless of source used by the manufacturing industries (Standard Industrial Classification categories 13, 14, and 20-39). The total industrial requirements are determined by combining the projected number of employees with the projected unit employee water use for each of the several industrial categories. Industrial water use in the study area for the year 2020 is estimated to be 288 mgd. The base data were obtained from an industrial survey of the study area and adjustments have been made for anticipated recirculation practices.

Power Generation Water Use

Consumptive use of water for thermal power generation is a part of the industrial requirement that has been determined separately. Information on future water use was gathered from power companies in the area and combined with data developed by the Federal Power Commission and the Edison Electric Institute for the Senate Select Committee on National Water Resources. Consideration was given to the general location of future power

generation installations and the projected needs apportioned throughout the study area according to assumed service areas for the several generating plants. The water requirements for this purpose are estimated to be 32 mgd in the year 2020. This water has been included in the estimate previously given for industrial water use.

Rural Water Use

An estimate of the rural water use was made so as not to understate the total water requirements of the study area. For purposes of this study, rural water requirements are assumed to consist of domestic water for that portion of the rural population not served by municipal water systems and water for the maintenance of livestock. The 2020 requirements for rural water are estimated to be 38 mgd based on a rural per capita use of 180 gallons per day, of which 80 gpcd is for the maintenance of livestock.

Irrigation Water Use

The greatest water needs in the study area are for irrigation. Irrigation water requirements are based on the water needs for the irrigation of rice, since over 98 percent of the irrigated acreage in 1960 was planted in this commodity. For purposes of projection, it was assumed that the acreage under cultivation for rice would remain at the 1960 level and the annual water need would be 4.5 feet per acre. On this basis, the 2020 water requirements for irrigation are estimated to be 449,000 acre-feet per year.

Water Quality Control

To attain full utilization of the water resources of Bayou Teche and Vermilion River for municipal, industrial, agricultural, and recreational purposes will require abatement of present and prevention of future pollution. Treatment alone at the present stage of its development is not sufficient to achieve desirable stream conditions in the watersheds.

Provision of supplemental water to control the quality of the waters in the Bayou Teche and Vermilion River will have many benefits. Some of the benefits derived by maintenance of low total dissolved solids concentrations are increased rice yields and improvements in the competitive position of the area in attracting industry. Similarly, preservation of an adequate level of dissolved oxygen in the basin waters will provide for a dependable and safe water supply and enhance the recreational attractiveness of the streams by providing a balanced ecology. Low flows will be less severe and pest breeding stagnant pools will be eliminated.

Of the several broad parameters presently available for the evaluation of water quality, biochemical oxygen demand (BOD), chlorides, and total dissolved solids were chosen for use in this study for the following reasons:

1. The principal causes of manmade pollution in the Teche-Vermilion system are: (a) raw sugar mill wastes; (b) industrial wastes from food processing; (c) domestic sewage; and (d) various other industrial wastes. All of the above contribute BOD and a variety of chemical constituents that can best be estimated as total dissolved solids.

2. The irrigation of rice is very important to the study area and chloride concentration is the best presently available indicator of rice irrigation water quality.

Based on the assumption that sufficient waste treatment will be provided to remove 90 percent of the biochemical oxygen demand, the 2020 requirement for water for quality control purposes is estimated to be 190 million gallons per day. Provision of this amount of water will maintain 3 mg/l of dissolved oxygen and less than 500 mg/l 42/ of total dissolved solids in the streams.

Sixty mgd of the above requirement is the amount needed for prevention of salt water intrusion in the Vermilion River. Salinity intrusion calculations were not made on Bayou Teche, since (1) there is no threat to underground aquifers; and (2) there is no significant irrigation development expected in the lower reaches of the stream which would be affected by salinity.

VII. WATER SUPPLY AND WATER QUALITY CONTROL PLAN

General

In order to supply the water needs shown in the previous section, a plan was developed utilizing all available water resources in the Teche-Vermilion basin. Water requirements over and above this quantity are planned to be supplied by a supplemental source--the project. A total water supply need analysis for the six-parish study area is shown in Figure VII-1. 43 44 46/

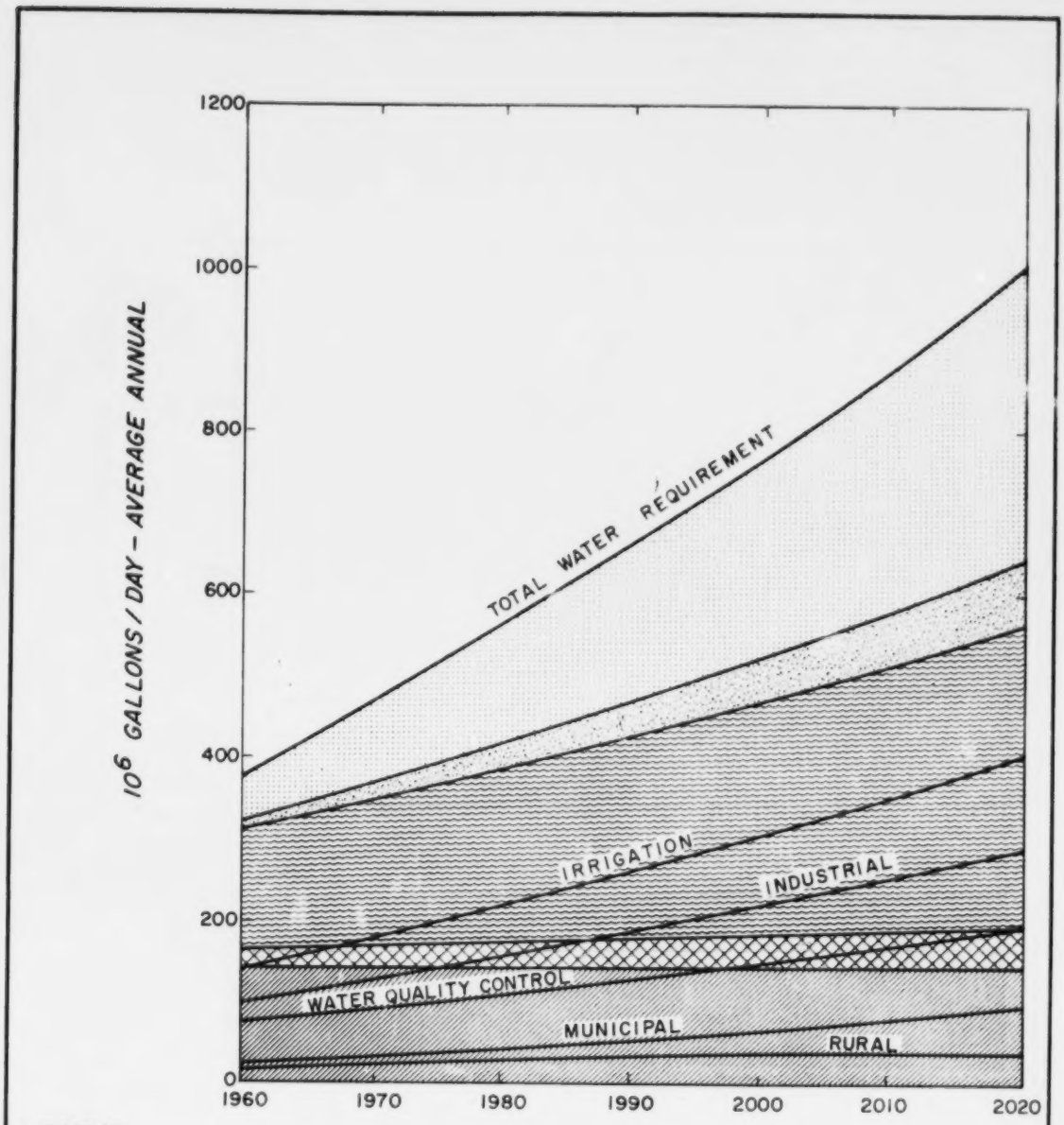
Teche-Vermilion Surface Water System Plan

A similar supply and need analysis for the Teche-Vermilion surface water system is shown in Figure VII-2. The net effective system streamflow available is based on monthly low flows with a 50-year recurrence interval for the periods January through March and September through December and on a seven day low flow with a 10-year recurrence interval for the irrigation season (April through August). The discharge frequency analysis for this system is shown in Appendix A.

As shown in Figure VII-2, the average annual supplemental surface water supply need in the year 2020 is 360 mgd. A monthly distribution of this quantity is shown in Figure VII-3. Supplemental surface water supply needs are greatest during the irrigation season, April through August. Since there is no storage involved in the project, the highest monthly requirement will determine the design capacity of the project pumping plant. This value is 810 mgd in the year 2020 as shown in Figure VII-4.

Alternatives

This report considers alternatives to satisfy only the municipal, industrial and water quality control portion of the supplemental surface water supply need (226 mgd--average annual basis). The most reasonable alternative to the project pumping plant is a reservoir with sufficient storage to yield 226 mgd located on Bayou Cocodrie near Clearwater, Louisiana. See Figure III-1.



LEGEND

- NET EFFECTIVE SYSTEM STREAMFLOW
- SURFACE SUPPLY FROM LOWER ATCHAFALAYA RIVER FOR PART OF ST. MARY PARISH (MORGAN CITY & VICINITY)
- GROUND WATER DEVELOPMENT
- REUSABLE RETURN FLOWS
- SUPPLEMENTAL SURFACE WATER SUPPLY NEED

WATER RESOURCES STUDY
BAYOU TECHE & VERMILION RIVER, LOUISIANA

STUDY AREA SUPPLY AND NEED ANALYSIS

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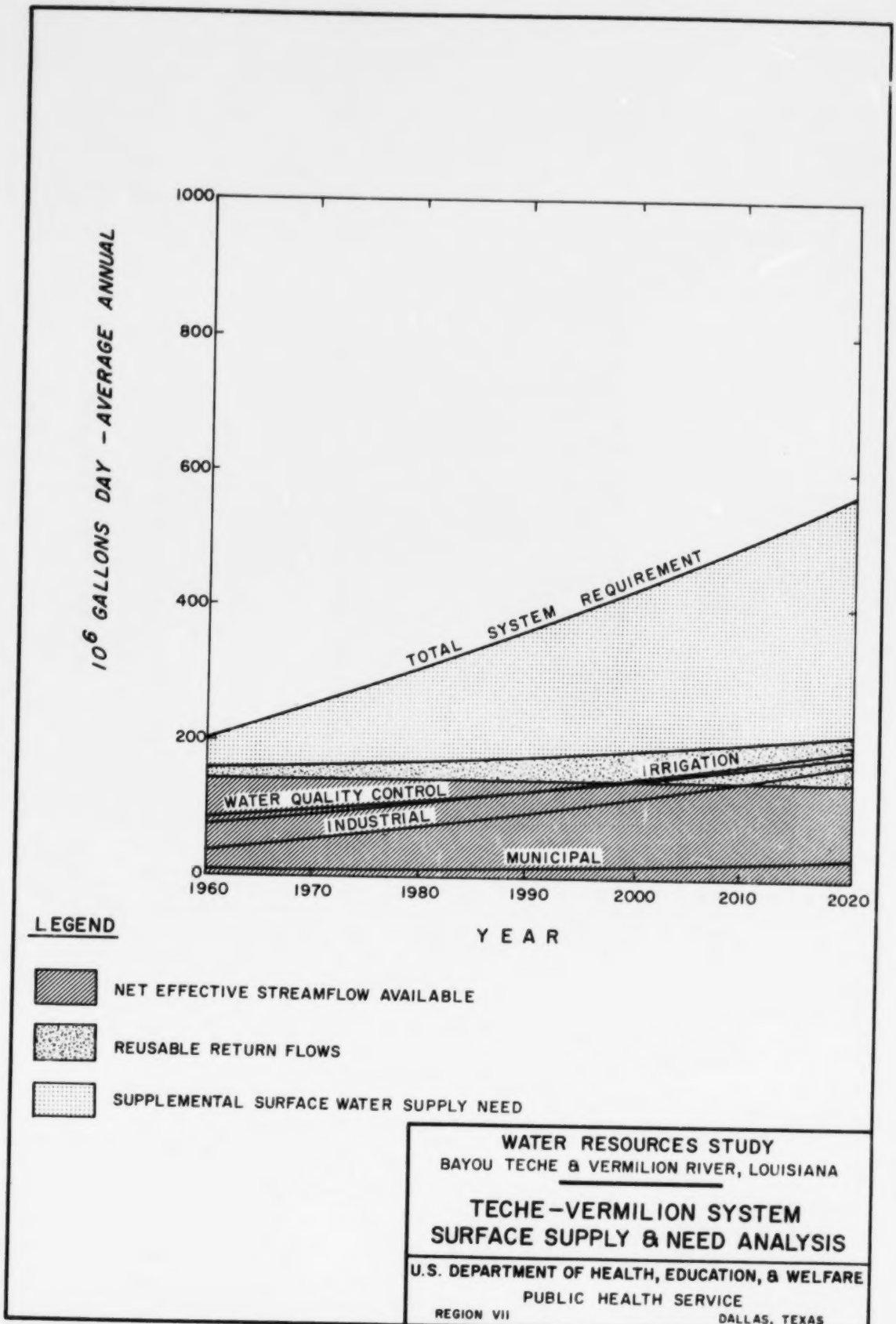
FIGURE VII-1


10^6 GALLONS DAY - AVERAGE ANNUAL
1000
800
600
400
200
0
1960
1970
1980
1990
2000
2010
2020
TOTAL SYSTEM REQUIREMENT
IRRIGATION
WATER QUALITY CONTROL
INDUSTRIAL
MUNICIPAL
YEAR
LEGEND
NET EFFECTIVE STREAMFLOW AVAILABLE
REUSABLE RETURN FLOWS
SUPPLEMENTAL SURFACE WATER SUPPLY NEED
WATER RESOURCES STUDY
BAYOU TECHE & VERMILION RIVER, LOUISIANA
TECHE-VERMILION SYSTEM
SURFACE SUPPLY & NEED ANALYSIS
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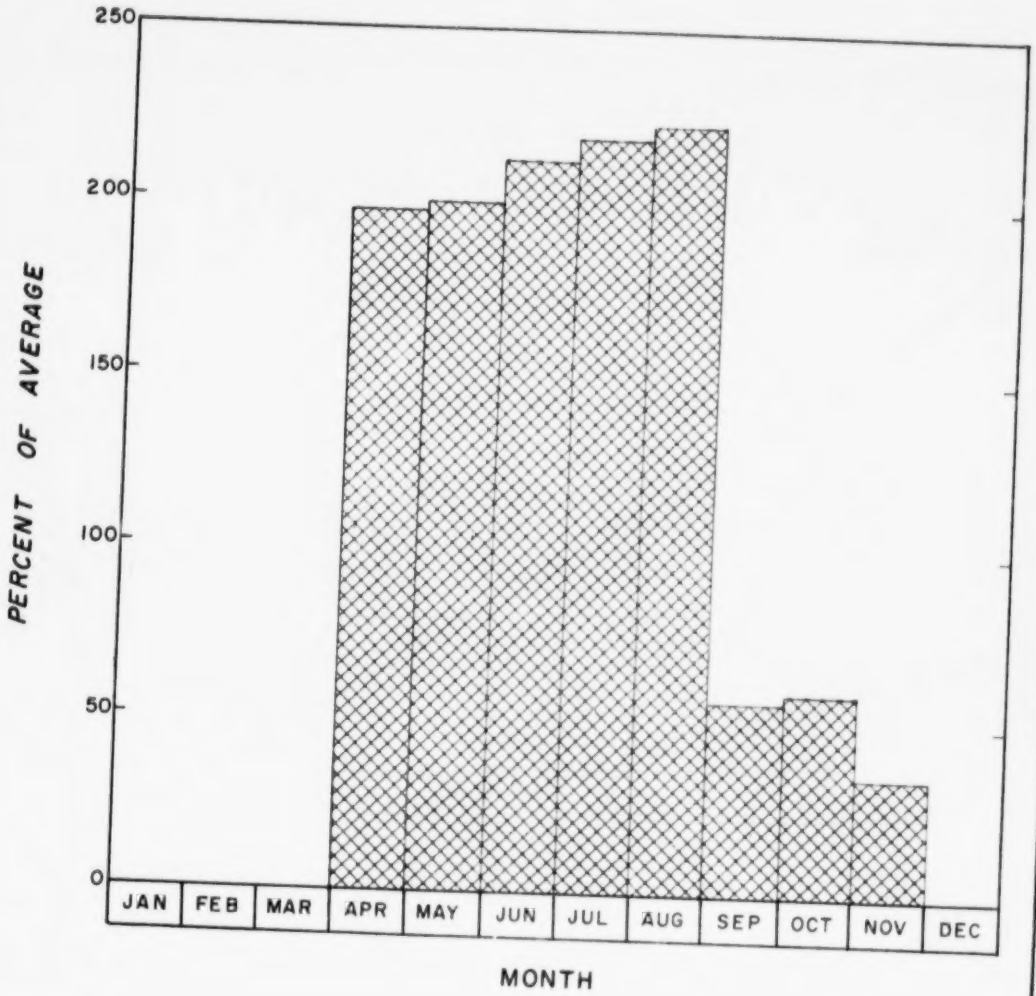
PUBLIC HEALTH SERVICE
REGION VII
DALLAS, TEXAS

FIGURE VII-2

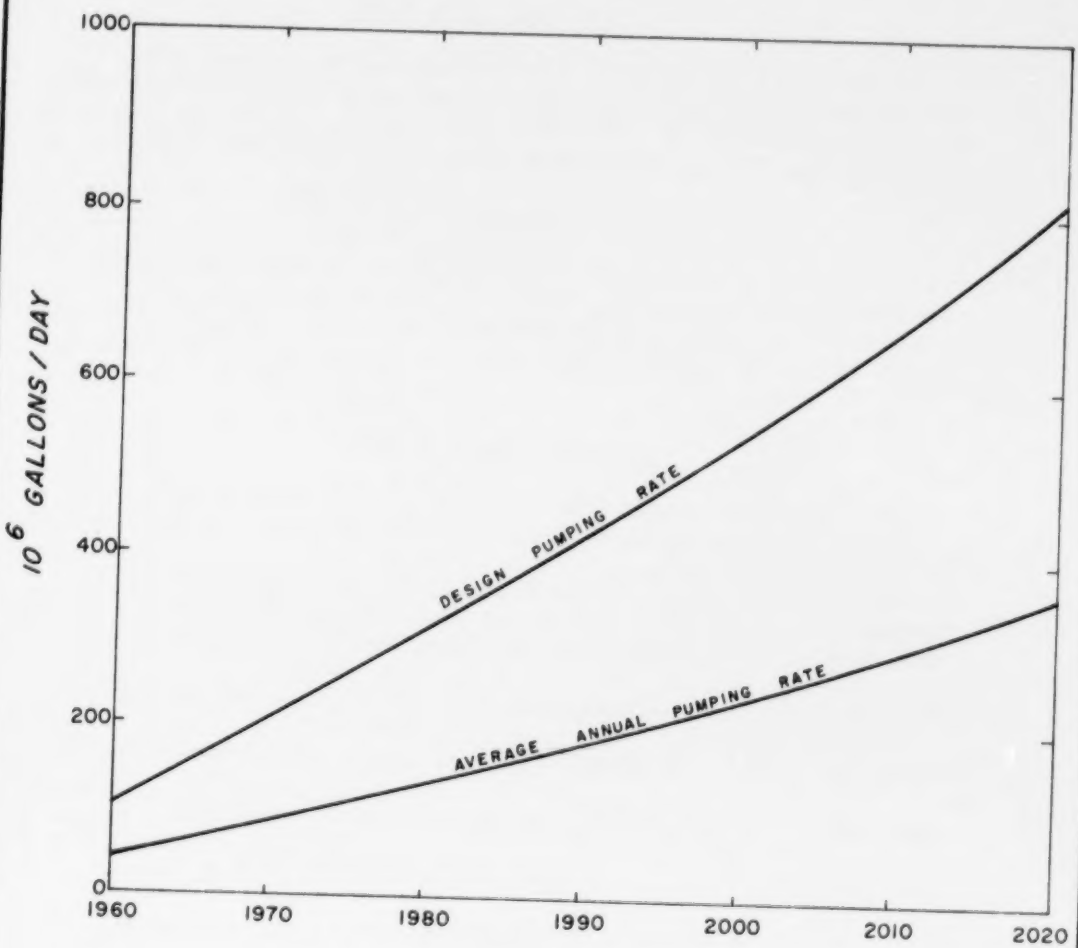


WATER RESOURCES STUDY
BAYOU TECHE & VERMILION RIVER, LOUISIANA

DISTRIBUTION OF SUPPLEMENTAL SURFACE WATER SUPPLY NEEDS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE VII-3



WATER RESOURCES STUDY
BAYOU TECHE & VERMILION RIVER, LOUISIANA

PUMPING RATES FOR SUPPLEMENTAL SURFACE WATER SUPPLY

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FIGURE VII-4

VIII. BENEFITS

Evaluation Methods [35/]

Two benefit evaluation methods are used in this report. These are (1) the alternative cost method; and (2) the evaluation of a loss function--in this case reduction in rice production due to salinity intrusion which would occur without the project.

Costs

For purposes of comparison of alternatives capital costs were converted to equivalent annual costs using an amortization period of 50 years and a non-Federal interest rate of 4 percent. The reported present worth of these annual costs refers to the year 1970.

Water Supply Benefits

Annual benefits for municipal and industrial water supply are attributable to the following project features:

1.	Pumping plant and appurtenances (enlargement of Bayou Courtableau Drainage Structure, inlet channel, control structure at Atchafalaya, Louisiana).	$184,400
2.	Bayou Fusilier control structure.	$5,700
3.	Loreauville Canal control structure.	$11,400
4.	Charenton Canal control structure.	$47,000
	Total annual water supply benefits.	$248,500

Benefit calculations are shown in Appendix B.

Water Quality Control Benefits

The following annual benefits attributable to the several project features are for water quality control.

1.	Pumping plant and appurtenances (enlargement of Bayou Courtableau Drainage Structure, inlet channel, control structure at Atchafalaya, Louisiana).	$182,200
2.	Bayou Fusilier control structure.	$5,600

3. Loreauville Canal control structure.	$11,200
4. The entire project through evaluation of rice production loss function.	$183,400
Total annual water quality control benefits from project.	$382,400

The water quality control benefits are considered widespread since (1) the waters of a large portion of the state are affected and (2) there are no identifiable beneficiaries.

Benefit calculations for water quality control benefits are shown in Appendix B.

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X. APPENDIX

APPENDIX A

HYDROLOGY

General

In the planning of a surface water supply system to satisfy future requirements, estimates of natural streamflow that can be expected to occur at some selected probability level must be made. These estimates are especially significant in the study of Bayou Teche and Vermilion River, since there is no surface storage anticipated.

Historical Flow

Stream discharge data in the area are very sparse. United States Geological Survey records [36-38] show only six active discharge stations in the watershed, and these have only short records. Stage-discharge records of the U.S. Army Corps of Engineers [39 40] are also available in the basin, however, the periods of record for useful points in the system are, in most cases, no longer than those of the United States Geological Survey.

Because of tidal influences, gaging station records are available only for the headwater areas of the streams. Gaging stations in the study area that were used in the study, along with the drainage area and period of record of each, are shown in Table A-1.

Table A-1 [36-38]

Study Area Gaging Stations Used

Station	Basin	Drainage Area (sq. mi.)	Period of Record
Bayou Teche at Arnaudville	Teche	1,531 [a]	1949 to date
Bayou Bourbeau at Shuteston	Vermilion	19.0	1942 to date
Bayou Carencro near Sunset	Vermilion	37.1	1943 to 1961
Vermilion River at Lafayette	Vermilion	[b]	1943 to 1952 [c]

a/ Due to interchange of flow between basins, the limits of the drainage area are more or less arbitrarily determined.
b/ Drainage area indeterminate.
c/ Miscellaneous measurement.

Methods of Analysis

Bayou Teche

Several methods of analysis to improve the statistical reliability of the streamflow records were suggested. Correlation with nearby stations to extend the records was not considered feasible because of the nature of the watershed and the insufficiency of records in nearby streams.

A second approach was to use the average annual runoff, coefficient of variation of annual runoff, and monthly distribution of runoff typical for the area as given in U.S. Geological Survey Circular No. 52 and U.S. Geological Survey "Water Resources Review" Supplement No. 2. This method was abandoned since the 35 percent coefficient of variation shown was considerably in excess of the 19.3 percent calculated from the observed data.

The third method tried and eventually used was an adaptation of a streamflow sequence synthesis technique. 31/ The intent here was to increase the statistical significance of the short observed records.

The first assumption used in this method was that a statistically normal population existed for each month of the year. The observed data appeared to fit a normal distribution nearly as well as a log transformation of the flows. Advantages to be gained from a log transformation of the flows were slight and did not seem to warrant the additional calculations involved. The following equation was used to generate the synthetic streamflow sequence.

$$Q_{x+1} = \overline{Q}_{y+1} + b_y(Q_x - \overline{Q}_y) + t_x \sigma_{y+1}(1-r_y^2)^{0.5}$$

Where: Q_x and Q_{x+1} (cfs) are discharges during the xth and (x+1)st month, respectively, computed from the start of the synthesized sequence.

$\overline{Q}_y$ and $\overline{Q}_{y+1}$ (cfs) are the mean monthly flows during the yth and (y+1)st month, respectively, within a repetitive annual monthly cycle.

b_y is the regression coefficient for estimating flow in the (y+1)st month from the yth month.

t_x is a term from a table of random normal numbers whose mean is 0 and variance is 1. 32/

σ_{y+1} is the standard deviation of flows in the (y+1)st month.

r_y is the correlation coefficient between flows in the yth and (y+1)st month.

Methods of Analysis

Bayou Teche

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b_y is the regression coefficient for estimating flow in the (y+1)st month from the yth month.

t_x is a term from a table of random normal numbers whose mean is 0 and variance is 1. 32/

σ_{y+1} is the standard deviation of flows in the (y+1)st month.

r_y is the correlation coefficient between flows in the yth and (y+1)st month.

The serial correlation parameters of monthly flows required for the above equation are shown in Table A-2.

Table A-2

Serial Correlation Parameters of Monthly Flows in Bayou Teche at Arnaudville Based on 14 Years of Record

Month	Regression Coefficient by $(cfs)^{-1}$	Correlation Coefficient r_y	Standard Deviation σ_y (cfs)	Mean Flow $\bar{Q}_y$ (cfs)
January	0.0933	0.1082	255	999
February	0.3530	0.3003	296	1,149
March	0.4954	0.3461	251	1,110
April	0.0078	0.0248	176	1,151
May	1.0757	0.7707	555	1,179
June	0.8478	0.6568	398	929
July	0.7895	0.7163	308	728
August	0.6020	0.5913	280	587
September	0.6296	0.5964	275	489
October	0.5051	0.6107	260	452
November	0.6748	0.6184	315	490
December	0.2092	0.1850	288	826

Seven of the twelve correlation coefficients shown above in Table A-2 are statistically significant for a sample of 14 pairs. The accepted minimum correlation ratio for statistical significance at the 95 percent level for this size sample is 0.5324. 33/

The lack of significant correlation between the late winter and spring months (December-January through April-May) is probably due to a combination of manmade controls and to the relatively large variance in rainfall and the associated runoff during these months. When runoff is high during these months, flow in the stream is regulated by the control structures on Bayous Darbonne and Courtableau that discharge through the West Atchafalaya Basin Protection Levee.*/ Flow through these structures can be in either direction, depending on the relative stages in the affected streams and the Atchafalaya Floodway. The weirs on Bayou Courtableau also control the flow in the system during periods of high runoff. Water in the stream flows over the weirs at stages above 18.0 feet (m.s.l.).

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* See discussion in section III of this report.

Using the recursion equation and the serial correlation parameters, flows were synthesized for a total period of 500 years and divided into ten sets of 50 years each.

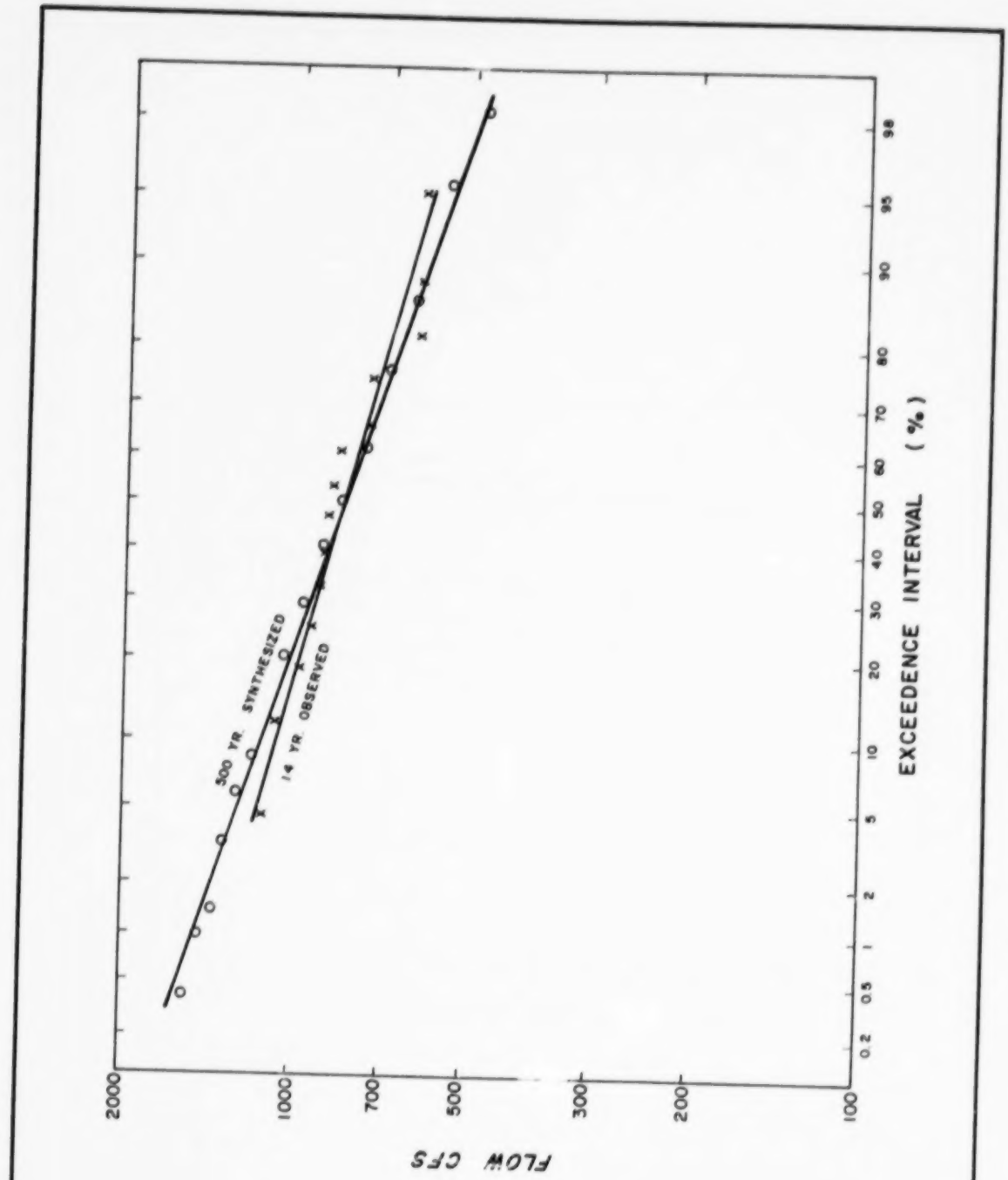
The mean monthly flows for the entire 500-year flow sequence agreed fairly well with the 14-year observed record, as shown below in Table A-3. A cumulative distribution showing both observed and synthesized average annual flows is shown in Figure A-1.

Table A-3

Comparison of Mean Monthly Flows
Bayou Teche at Arnaudville
(cfs)

Month	Observed Record (14 yrs.)	Synthesized (500 yrs.)
January	999	995
February	1,149	1,147
March	1,110	1,115
April	1,151	1,154
May	1,179	1,169
June	929	948
July	728	751
August	587	615
September	489	512
October	452	471
November	490	513
December	826	823
Total	10,189	10,213
Average	849	851

The ten sets of 50-year sequences were used to describe the variation of flow at a given exceedence interval within the assumed parent population (500 year). Although not incorporated into the design, this information provides some insight into the magnitude of the departure from the flow at the design exceedence interval that could occur during the life of the project. A comparison of statistical parameters for the ten 50-year flow sequences is shown in Table A-4. A cumulative distribution of the flows at several exceedence intervals is illustrated in Figure A-2.



WATER RESOURCES STUDY
BAYOU TECHE & VERMILION RIVER, LOUISIANA

DISCHARGE FREQUENCY ANALYSIS
BAYOU TECHE AT ARNAUDVILLE

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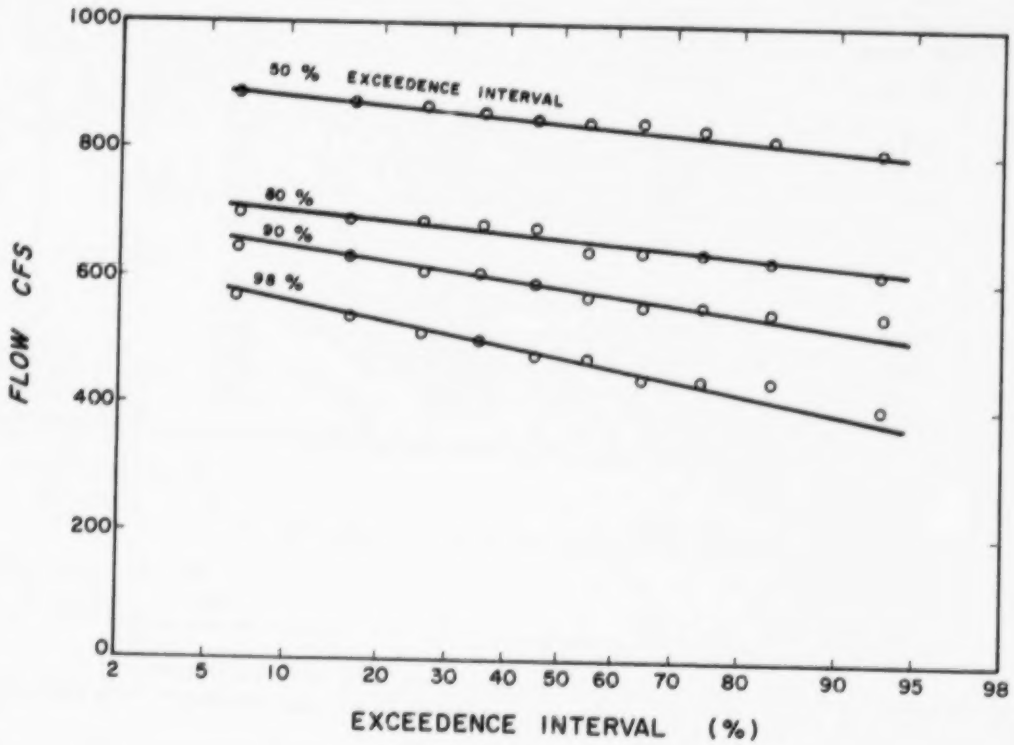
FIGURE A-1



WATER RESOURCES STUDY
BAYOU TECHE & VERMILION RIVER, LOUISIANA

VARIANCE OF FLOW AT VARIOUS EXCEEDENCE INTERVALS FOR TEN 50-YEAR SYNTHESIZED SEQUENCES BAYOU TECHE AT ARNAUDVILLE

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE A-2

Table A-4

Comparison of Statistical Parameters for Ten Sets of 50-Year Synthesized Flow Sequences on an Annual Average Basis
(All Flows are in cfs)

Set	50-Year Mean Flow	Std. Dev.	50-Year 90 Percent Low Flow	50-Year 98 Percent Low Flow
1	861	199	610	515
2	883	211	630	540
3	821	216	560	475
4	878	198	645	570
5	804	216	543	442
6	850	240	560	442
7	854	242	550	400
8	839	224	575	480
9	869	214	595	445
10	849	194	607	500
Total 500-year Sequence	851	214	588	490
Observed 14-year Record	841	166	660	580

To determine the design streamflow available, the synthesized streamflow sequence was used in the following manner.

1. Average annual flows at various exceedence intervals were calculated.

2. A distribution of the average annual flow by months was computed from the monthly median flows obtained from the 500-year sequence. These are shown below in Table A-5 as percentages of the average annual flow.

Table A-5

Monthly Flow Distribution as Percentage of Average Annual Flow Based on 500-Year Synthesized Flow Sequence

Month	Percent of Average Annual Flow	Month	Percent of Average Annual Flow
January	116.9	July	88.2
February	134.8	August	72.3
March	131.0	September	60.2
April	135.6	October	55.3
May	137.3	November	60.3
June	111.4	December	96.7

The irrigation period (April through August) of each year requires more detailed analysis, and seven day low seasonal volumes were computed for these months. In view of the close agreement between the observed record and synthesized flow sequence for the entire year, the analysis of the irrigation season was restricted to observed flows. A discharge-frequency analysis on this basis gave the values shown in Table A-6.

Table A-6

Seven Day Low Flows During the Irrigation Season Bayou Teche at Arnaudville

Exceedence Interval (Percent)	Seven Day Low Flow (cfs)
50	386
80	210
90	116
Standard Deviation	211

Vermilion River

Reliable estimates of flow in the Vermilion River basin were more difficult to determine than for Bayou Teche. Unlike Bayou Teche, the Vermilion River has a well defined drainage basin over

its entire length, and estimates of the runoff at various points in the stream were needed to complete the water supply plan. Gaging stations with usable records (Bayous Bourbeau and Carencro) measure the runoff from only 8.6 percent or 56.1 square miles of the 652 square mile basin. All flow determinations on the Vermilion River assume that the control structures on Bayou Fusilier and Ruth Canal are closed, allowing no flow to enter from Bayou Teche.

Flow sequences for Bayous Bourbeau and Carencro were synthesized, and the values thus obtained were reduced to unit discharges and then proportioned along the river on an areal basis. The statistical reliability of this analysis was similar to that described above for Bayou Teche at Arnaudville. The results are summarized below in Table A-7.

Table A-7

Summary of Discharge-Frequency Analysis for the Vermilion River

Month	Percent of Average Annual Flow	Unit Monthly Flow (cfs/sq. mi.) 98 Percent Exceedence	Unit Monthly Flow (cfs/sq. mi.) 90 Percent Exceedence
January	213.1	0.745	1.204
February	251.1	0.886	1.428
March	142.1	0.497	0.802
April	99.3	0.348	0.564
May	136.9	0.481	0.775
June	33.9	0.119	0.192
July	74.2	0.262	0.421
August	37.1	0.130	0.211
September	20.4	0.073	0.116
October	7.0	0.024	0.041
November	11.7	0.043	0.068
December	173.2	0.610	0.986

It is unfortunate that so large a part of the available water supply in the Vermilion River basin had to be computed by indirect methods. This was necessary because of the lack of sufficient stream gaging records in the basin.*/

As was done in Bayou Teche, flows during the irrigation season were analysed on a seasonal seven day low basis. This analysis showed that there was no flow for many seven day periods of each irrigation season during the period of record.

Net Effective System Streamflow

The parameter of net effective system streamflow used in this report refers to that flow in the stream that is used to satisfy the requirements. During some periods of the year, flow in the stream exceeds the requirement. Since there is no storage, this excess flow is considered lost to the system. Therefore, the net effective system streamflow shown in section VII of this report refers only to the natural system streamflow that is used in satisfying the projected water requirements. This is calculated on a monthly basis and a weighted average determines the annual value shown.

Conclusion

The limitations of the methods applied to the computations of flow in this report must be recognized. Use and interpretation of the results should be made with the realization that probable errors may be large and are inherent in hydrologic studies where estimates of streamflow are required.

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*/ The flow in the lower reaches of this river is unmeasurable with presently available instruments because of extremely low velocities and frequent flow reversals.

APPENDIX B

BENEFIT CALCULATIONS

1. The most reasonable alternative to Bayou Courtableau pumping plant and appurtenances is Cocodrie Reservoir.

   From Water Supply and Need Analysis:

   50.3% is attributable to Water Supply
   49.7% is attributable to Water Quality Control

   Total Requirement: 226 mgd

   From Proposed Plan for Supplementing Low Flows in Bayous Teche and Vermilion, Louisiana Department of Public Works, May 1961:

   Cost of Cocodrie Reservoir to yield 210 mgd = $5.3 million

   ∴ Cost to yield 226 mgd = 5.3 X 226 ÷ 210 = $5.7 million

   Annual Cost @ 3% for 50 years--

(5.7 million) (0.03887)	= $221,600
Annual Operation and Maintenance	= 145,000
Total Annual Cost	= $366,600

   Attributable to M&I Water Supply:
   (0.503)($366,600) = $184,400

   Attributable to Water Quality Control:
   (0.497)($366,600) = $182,200

2. Benefits Attributable to Control Structures:

   a. Bayou Fusilier Control Structure: The benefits attributable to this structure are equivalent to approximately 25 percent of the additional flow that would be required in Bayou Teche during the sugarcane grinding season, because of loss to Vermilion River in the absence of the structure.

   From "1" above--Value of M&I and Water Quality Control Water = $366,600/yr. or 0.4¢/1,000 gal.

Water Requirement in Bayou Teche during Cane Grinding--11,300 mil. gal.

Additional Requirement-- 0.25(11,300 mil. gal.)	= 2,825 mil. gal.
Value--2,825 X 1,000 X $0.004	= $11,300/year
Attributable to M&I Water Supply-- (0.503)($11,300)	= $ 5,700
Attributable to Water Quality Control-- (0.497)($11,300)	= $ 5,600

b. Loreauville Canal Control Structure: The benefit from this structure is equivalent to approximately 50 percent of additional flow that would be required in Bayou Teche during the sugarcane grinding season. These benefits are calculated the same way as in "a" above.

∴ Benefit attributable to M&I Water Supply	= $11,400
Benefit attributable to Water Quality Control	= $11,200

c. Charenton Canal Control Structure: The most reasonable alternative to this structure is a water supply for the city of Franklin, Louisiana, from Grand Lake in the Atchafalaya River basin.

Requirement = 16.4 mgd

37,000 feet of 30" pipeline @ $15/foot	= $555,000
Lake Intake Structure (l.s.)	= 10,000
Pumping Station (l.s.)	= 110,000
Valve, Fittings, and Special Construction	= 65,000
Subtotal	$740,000
Engineering and Contingencies (10%)	= 74,000
Total	$814,000
Amortize @ 3% for 50 years-- Annual Cost	= $ 31,600
Annual Operations and Maintenance	= 15,400
Total Annual Benefit	$ 47,000

3. Water quality control benefits due to the loss sustained by rice in the absence of the project: This loss is restricted to the lower reaches of the Vermilion River and is determined as follows:

Assumptions

a. Rice acreage irrigated from Vermilion River--36,000 acres distributed evenly along the river from river mile 5.0 to 50.0.

b. The average yield per acre for the 50-year period (1970-2020) is 25.0 barrels/acre. This is based on rice yield projections by the U.S. Department of Agriculture for the U.S. Study Commission-Texas.

c. The price of rice assumed to prevail throughout the period is $7.50 per barrel.

d. The salinity of water available for irrigation is based on weekly low flows with a 10-year recurrence interval.

e. The loss incurred is twofold: (1) loss due to reduction in yield and (2) loss due to reduction in quality (linear variations from $1.2/barrel @ 1,000 mg/l Cl^- to $0.10 @ 300 mg/l Cl^-).

The length of the salt water wedge was calculated from the following equation contained in National Bureau of Standards Report 1700, Sixth Progress Report on Model Laws for Density Currents, by Garbis H. Keulegan, June 2, 1952.

$$L_1/D = 0.009\ (V_s\ D/N)^{0.75}\ (V_x/V_s)^{-3.6}$$

Where: L_1 = Length of salt water wedge
D = Depth of channel

$$V_s = \sqrt{\left(d_x - d_y \Big/ \frac{d_x + d_y}{2}\right)(gD)}$$

d_x = Density of water in bay
d_y = Density of water in river
g = Acceleration due to gravity
V_x = Velocity of flow in river
N = Kinematic viscosity of water

From the results of this equation and from an assumed channel configuration, it was possible to construct a chloride profile.

From data contained on page 391 of "Water, The Yearbook of Agriculture, 1955", a curve of chlorides versus percent reduction in rice yield was constructed.

The above data together with the quality reduction assumption shown previously in assumption "e" gave the following:

(1) Acreage affected = 26,800

(2) Annual loss to rice crop in absence of the project = $183,400

Two other evaluation methods were considered in calculating water quality control benefits due to loss of rice production. These were:

1. A salt water barrier on Vermilion River as an alternative.
2. Average loss of rice during the past 15 years of record.

The salt water barrier was not used due to its excessive cost. Historical rice production records were not used because: (1) they are not tied to any probability level; (2) they do not consider increases in rice yields during the life of the project, and (3) the losses are obtained by comparison with another area and variations in soil types and management practices are neglected.